US Army Corps
of Engineers

Final
TECHNICAL MEMORANDUM
Evaluation of Dose and Risk Models Utilized for the Hunters Point Naval Shipyard

Prepared by USACE Radiation Safety Support Team

Prepared for USEPA

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List of Acronyms and Abbreviations

AM	Action Memorandum
ANL	Argonne National Laboratory
BDCC	Building Dose Compliance Calculator
BPRG	Building Preliminary Remediation Goal
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	Conceptual Site Model
DCF	Dose Conversion Factor
FGR	Federal Guidance Report
HEAST	Health Effects Assessment Summary Tables
HPNS	Hunters Point Naval Station
ICRP	International Commission on Radiological Protection
ORNL	Oak Ridge National Laboratory
Rem	Roentgen Equivalent Man
RESRADBLD	RESRAD-BUILD
RG	Remediation Goal
RME	Reasonable Maximum Exposure
RSST	Radiation Safety Support Team
SF	Slope Factor
Sv	Sievert
TM	Technical Memorandum
USACE	US Army Corps of Engineers
USDOE	US Department of Energy
USDON	US Department of the Navy
USEPA	US Environmental Protection Agency

EXECUTIVE SUMMARY

The purpose of this Technical Memorandum (TM) is to document the evaluation of dose and risk models conducted by the U.S. Army Corps of Engineers (USACE) Radiation Safety Support Team (RSST) at the request of the U.S. Environmental Protection Agency (USEPA) as they relate to the contamination and remediation goals at/for the Hunters Point Naval Shipyard (HPNS).

USACE general approach was to assist USEPA in understanding key dose and risk modeling differences as they relate to the work conducted by the U.S. Department of the Navy (USDON).

During the process multiple discussions were held between USACE and USEPA. Those discussions resulted in four main questions. Those questions are evaluated in this TM. The answers to questions one and two comprise the conclusions of this TM while the answers to questions three and four comprise the recommendations of this TM.

The conclusions of this evaluation, captured by answering questions one and two, are below.

1. Why do results differ between RESRADBLD and both the BDCC and BPRG calculators?

Significant differences exist between the RESRADBLD and USEPA calculators. These include: Dose Conversion Factor (DCF) and Slope Factor (SF) selection; conceptual exposure model differences such as six (6) sources versus one (1); ingestion and transfer factors; and, source removal mechanisms such as air exchanges, cleaning, and radioactive decay.

2. What can be done to reduce the differences between model results?

The USACE approach demonstrates that there are several things that can be done to reduce the differences between the models.

a. Establishing a consistent source and receptor conceptual site model to be utilized by both the Calculators and RESRADBLD. As an example, adding the walls and use of direct ingestion factors to the RESRADBLD HPNS model and use the center receptor location in the USEPA calculators.
b. Using the SF and DCF editors to set these factors equal in each model.
c. Set common media/pathway of concern (Air, Dust, 3D external).
d. Use post output processing of results to modify results (e.g. determine and subtract the exposure from the ceiling source in the Calculators).
e. Multiple runs of the Calculators to account for radioactive decay could be done or use output option two (2) site specific user provided and change

progeny half-lives to match parent as well as performing a sensitivity analysis in RESRADBLD for parameters that cannot be changed.

The recommendations from this evaluation, captured by answering questions three and four, are below.

3. What should USEPA consider in determining the protectiveness of the HPNS criteria?

Consistent and realistic Conceptual Site Model. In addition to the model differences and varying input parameters discussed herein USEPA should consider the expected dust levels at HPNS post remediation. Survey data has historically indicated that there is little to no residual activity that is removable. Therefore, it is unlikely that significant contaminated dusts will remain and as such use of the air and dust calculator models may be overly conservative.

Model uncertainty should be considered. As approximations, all models have an associated uncertainty which should be considered. Using the probabilistic report of RESRADBLD or uncertainty analysis may demonstrate a range of results or an uncertainty that provides justification given the calculator results. Additionally, it should be noted that FGR-13 discusses significant uncertainty in slope factors for key HPNS isotopes of concern such as Ra-226. As such, significant uncertainty exists in risk outputs and this uncertainty should be considered when comparing differences in risk models.

Consider use of RESRADBLD given its flexibility. Alternatively, A risk assessment could be performed on the USDON proposed RGs without using RESRADBLD or BPRG (e.g. hand calculations, MCNP, GoldSim, RAGS, etc.).

4. What recommendations, if any, could be provided by USEPA to USDON regarding modeling at HPNS?

Consistent and realistic Conceptual Site Model. Recommend that the USDON provide modeling better correlated to the conditions found at HPNS and consider using specific DCFs and SFs agreed to by both USDON and USEPA.

a. The removable fraction (RF) of 0.2 seems high. Based on reported wipe sample data it is recommended that a RF of zero or 0.01 may be more appropriate.
b. Account for direct ingestion in the RESRADBLD model.
c. Expected contamination (isotopes and mixtures) in Buildings should be realistically grouped and model runs conducted per group.
d. Contamination of the four walls of a room, rather than just floor contamination, be modeled in the RESRADBLD model. Source area should be considered as well as it is unlikely that entire floors and walls will be contaminated uniformly.

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this Technical Memorandum (TM) is to document the evaluation of dose and risk models conducted by the U.S. Army Corps of Engineers (USACE) Radiation Safety Support Team (RSST) at the request of the U.S. Environmental Protection Agency (USEPA) as they relate to the contamination and remediation goals at/for the Hunters Point Naval Shipyard (HPNS).

USACE general approach was to assist USEPA in understanding key dose and risk modeling differences as they relate to the work conducted by the U.S. Department of the Navy (USDON). This TM also provides recommendations for USEPA to consider while interpreting and communicating dose and risks at the HPNS.

1.2 EVALUATION INFORMATION

1.2.1 Background

In support of the current five-year review, the USDON has evaluated the protectiveness of the current building surface remediation goals (RGs) for future occupants, that include both indoor workers and residents. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), cleanup goals are considered protective if excess cancer risks from site exposures remain within the excess lifetime cancer risk range of 10-4 to 10-6. The USDON used the model RESRAD-BUILD (RESRADBLD) to estimate radiation doses and risks from exposure to surface radiological contamination. Where applicable, the input parameters in RESRADBLD were adjusted to be consistent with the default parameters used in both the USEPA Building Dose Compliance Concentrations for Radionuclides (BDCC) and Building Preliminary Remediation Goals for Radionuclides (BPRG) online calculators, herein referred to as the calculator(s). The USDON also generated two sets of risk estimates using the BPRG calculator. One set used USEPA default input values; the other set used modified values proposed by the USDON, as summarized in Table 3.4.2.

USEPA initially requested USACE evaluation of the differences between the RESRADBLD model and USEPA dose and risk models as applicable to HPNS contamination and the USDON calculations.

1.2.2 Pertinent Site Information

HPNS was placed on the National Priorities List in 1989 and the USDON has been undertaking response actions under its CERCLA authority in each parcel. These actions are conducted to ensure radionuclide-specific radioactivity concentrations on building surfaces do not exceed the RGs stated in the 2006 Action Memorandum (AM) (NAVFAC, 2006).

Table 1. Current Building Surface Remediation Goals from 2006 HPNS Action Memorandum

Radionuclide of Concern	Building Surface Remediation Goals (dpm/100 cm^2)
Americium (Am)-241 (^{241}Am)	100
Cesium (Cs)-137 (^{137}Cs)	5,000
Cobalt (Co)-60 (^{60}Co)	5,000
Europium (Eu)-152 (^{152}Eu)	5,000
Eu-154 (^{154}Eu)	5,000
Plutonium (Pu)-239 (^{239}Pu)	100
Radium (Ra)-226 (^{226}Ra)	100
Strontium (Sr)-90 (^{90}Sr)	1,000
Thorium (Th)-232 (^{232}Th)	36.5
Tritium, H-3 (^{3}H)	5,000
Uranium (U)-235+D (^{235}U)	488

It should be noted that ROD stated limits are identical to the Table 1 values and removable surface activity limits are stated as 20 percent of the values. There is some ambiguity of the question of how removable contamination limits are applied. The original Action Memorandum footnotes suggest that removable contamination limits may only apply to release of equipment and not to building surfaces. This should be discussed between USDON and USEPA.

2.0 EVALUATION APPROACH AND METHODOLOGY

2.1 APPROACH

USACE evaluated differences between the USDON utilized RESRADBLD model and the USEPA dose and risk models. Understanding the differences between the models is expected to assist USEPA in determining whether it can support the USDON modeled approach at HPNS. The intent of the USACE evaluation was to assist USEPA in understanding key modeling differences.

The initial intent was to answer the question of "Why do results differ between RESRADBLD and both the BDCC and BPRG calculators?" During the process of answering that question, multiple discussions were held between USACE and USEPA. Those discussions resulted in additional questions. The resulting focus of the evaluation is to answer the below questions:

1. Why do results differ between RESRADBLD and both the BDCC and BPRG calculators
2. What can be done to reduce the differences between models results

3. What should USEPA consider in determining the protectiveness of the HPNS criteria; and
4. What recommendations, if any, could be provided by USEPA to USDON regarding modeling at HPNS?

2.2 METHODOLOGY

The USACE utilized a very simple methodology:

1. Research the models.
    a. Terms
    b. Parameters
    c. Equations
2. Evaluate key differences
3. Iterative experiments. Changed parameters in models to identify the key factors in model output (result) differences.

3.0 Evaluation Discussion and Findings

The three (3) computer models evaluated are RESRADBLD (USDON) , BDCC (USEPA), and BPRG (USEPA). All models were developed by the U.S. Department of Energy (USDOE) National labs. The RESRAD family of codes developed by Argonne National Laboratory (ANL) and the BDCC and BPRG developed for USEPA by Oak Ridge National Laboratory (ORNL).

A primary difference between USDON and USEPA models is the starting points for source, modeling. RESRADBLD starts with a defined source and calculates dose and risk from that source including changes to the source and associated media. As an example a source in RESRADBLD may radiologically decay, be eroded and contaminate other media such as air, become dust, or removed by physical processes such as air exchanges. The USEPA calculators start with a contaminated media (air, dust, direct exposure) and generally do not account for changes in source activity, with the exception of physical removal by cleaning. Additionally, the calculators allow half life adjustments to account for decay in decay chains.

Table 3.0 presents a comparison of model approaches based on exposure route.

Table 3.0 Comparison of Model Approaches Based on Exposure Route

Exposure Route	RESRAD Build[A]	BPRG[B]
External (direct)	Calculates dose and risk. Risk determined by dose to risk conversion factor (0.076/Sv)	3D-External model option calculates risk. Dose is calculated for 1 year by BDCC.
External (indirect)	Calculates dose and risk. Risk determined by dose to risk conversion factor (0.076/Sv).	Dust model option calculates risk. Dose is calculated for 1 year by BDCC. Dust activity concentration is a required input.
Ingestion (direct)[E]	Calculates dose and risk. Assumption inputs change based on source type. Summed in output with indirect ingestion.[C]	No distinction between direct ingestion and indirect ingestion is made. Dust model option calculates risk. Dose is calculated for 1 year by BDCC. Dust activity concentration is a required input.
Ingestion (indirect)	Calculates dose and risk.[D] Assumption inputs change based on source type. Summed in output with direct ingestion.[C]	No distinction between direct ingestion and indirect ingestion is made. Dust model option calculates risk. Dose is calculated for 1 year by BDCC. Dust activity concentration is a required input.
Inhalation	Calculates dose and risk. Calculates activity concentration in air. [D]	Air model option calculates risk. Dose is calculated for 1 year by BDCC. Air activity concentration is a required input.
Immersion	Calculates dose and risk. Calculates activity concentration in air. [D]	Air model option calculates risk. Dose is calculated for 1 year by BDCC. Air activity concentration is a required input.
Radon	Calculates dose and risk.	Calculates dose and risk from media specific models.

[A] Sums dose and risks in one model run and presents in separate reports.

[B] Exposure routes selected in model. Separate models for dose and risk.

[C] Can run model twice (with and without air fraction) to distinguish between indirect and direct.

[D] Calculates activity in dusts and air using room (e.g. ventilation), resuspension factor, deposition velocity, source parameters (e.g. air fraction), and other factors.

[E] This refers to direct ingestion of the source material. RESRADBLD calculates direct ingestion of source and indirect ingestion from source material becoming dust. BPRG starts with a dust concentration thus ingestion would be direct (dust is the source).

3.1 RESRAD-BUILD in General

RESRAD-Build Version 3.5 (http://resrad.evs.anl.gov/codes/resrd-build/) is a downloadable computer code, developed by the USDOE-ANL.

The RESRADBLD code is approved by Nuclear Regulatory Commission to evaluate contaminated buildings involved in decommissioning and license termination. Exposures analyzed for a receptor may result from direct external radiation (from contamination sources and submersion in contaminated air), inhalation of airborne contaminated dust particles, inhalation of radon, and incidental ingestion of contaminated dust particles. The building under consideration can consist of up to three rooms, with air exchange between the rooms and the outside environment. Up to 10 radiation sources and 10 receptors can be specified in a single calculation. Radiation sources and receptors can be located in any of the rooms, with specified coordinates and characteristics such as time fraction in the room, breathing, and incidental ingestion rate for the receptors and the orientation, shape, dimensions, and erosion rate for the contamination sources. The contamination sources can assume a point, line, plane, or volume geometry and can be on the surface or within the building, equipment, or furniture material. Radiation shielding between receptors and contamination sources can be specified and is factored into the external dose calculation. Users choose appropriate input parameter values to simulate a building occupancy (e.g., residential use and office worker) or remediation (e.g., decontamination worker and building renovation worker) scenario. Outputs from the RESRADBLD model are both risk and dose.

3.2 BDCC in General

The USEPA had ORNL develop the BDCC tool (https://epa-bdcc.ornl.gov/) to help standardize the evaluation and cleanup of radioactively contaminated sites where doses are being assessed. It provides a methodology for radiation professionals to calculate dose-based, site-specific, dose compliance concentrations (BDCCs) for radionuclides inside of buildings while complying with a dose-based standard as an Applicable or Relevant and Appropriate Requirement. BDCCs are isotope activities that correspond to fixed levels of dose (e.g., mrem) inside a building. Dose Coefficients (DCFs) for a given radionuclide represent the dose equivalent per unit intake (i.e., ingestion or inhalation) or external exposure of that radionuclide. In dose assessments, these DCFs are used in calculations with radionuclide concentrations and exposure assumptions to estimate dose from exposure to radioactive contamination. The calculations may be rearranged to generate BDCCs for a specified level of dose. DCFs may be specified for specific body organs or tissues of interest or as a weighted sum of individual organ dose, termed the effective dose equivalent. These DCFs may be multiplied by the total activity of each radionuclide inhaled or ingested per year or the external exposure concentration to which a receptor may be exposed to estimate the dose to the receptor. Exposure to contaminated air, dust, and 3D external (fixed contamination) media are considered.

3.3 BPRG in General

The BPRG calculator (https://epa-bprg.ornl.gov/) is a tool that the USEPA ha ORNL develop to help standardize the evaluation and cleanup of radioactively contaminated buildings. This BPRG provides a recommended methodology for radiation professionals to calculate risk-based, site-specific, concentrations for radionuclides that comply with a risk-based standard, such as the 1E-04 to 1E-06 NCP risk range. Preliminary Remediation Goals for Radionuclides in Buildings (BPRGs) are reasonable maximum exposure (RME) risk concentrations derived from standardized equations that combine exposure information and toxicity information in the form of slope factors (SFs).

Recommended BPRGs are presented for resident and indoor worker exposure. The risk based BPRGs for radionuclides are based on the carcinogenicity of the contaminants. Exposure to contaminated air, dust, and 3D external (fixed contamination) media are considered.

3.4 MODELED DISCUSSIONS

3.4.1 Inputs

Contaminant and activity conversions for the different model input parameters are shown in Table 3.4.1.

Table 3.4.1 Contaminants and Activity Conversions

Parent ROC	Contributing Progeny	Input Concentration (dpm/m^2)	EPA Model Conversions	
			pCi/m2	pCi/cm2
^{241}Am		10,000	4505	0.450
^{60}Co		500,000	225225	22.523
^{137}Cs	^{137m}Ba	500,000	225225	22.523
^{152}Eu		500,000	225225	22.523
^{154}Eu		500,000	225225	22.523
^{3}H		500,000	225225	22.523
^{239}Pu	^{235m}U	10,000	4505	0.450
^{226}Ra	^{222}Rn+D	10,000	4505	0.450
	^{210}Pb+D	10,000	4505	0.450
	^{210}Po+D	10,000	4505	0.450
^{90}Sr	^{90}Y	100,000	45045	4.505
^{232}Th		3,650	1644	0.164
	^{228}Ra+D	3,650	1644	0.164
	^{228}Th+D	3,650	1644	0.164
^{235}U	^{231}Th	48,800	21982	2.198

General input parameters and values for a future resident used in the RESRAD-BUILD and BPRG Calculator models are listed in Table 3.4.2.

Table 3.4.2 General Input Parameters

Variable	Description	RESRAD-BUILD			BPRG Calculator - Settled Dust		
		Units	Model Default Value	User Input Value	Units	Model Default Value	User Input Value
	Breathing Rate - Adult	m^3/day	18	20	Inhalation not Evaluated		
	Breathing Rate - Child	m^3/day	18	10	Inhalation not Evaluated		
	Building Air Exchange Rate	$hour^{-1}$	1.5	0.45	NA		
	Evaluation Time - Resident Adult (i.e., model time-step for starting exposure)	yrs	0	6	NA		
	Evaluation Time - Resident Child (i.e., model time-step for starting exposure)	yrs	0	0	NA		
ED_{res}	Exposure Duration - Total Residence Time ("Lifetime in RESRAD-BUILD Model)	days	365	9,490 (26 yrs)	yr	26	26
$ED_{res\text{-}a}$	Exposure Duration - Resident Adult	days	365	7,300 (20 yrs)	yr	20	20
$ED_{res\text{-}c}$	Exposure Duration - Resident Child	days	365	2,190 (6 yrs)	yr	6	6
EF_{res}	Exposure Frequency - Resident	day/yr	NA		day/yr	350	350
$EF_{res\text{-}a}$	Exposure Frequency - Resident Adult	day/yr	NA		day/yr	350	350
$EF_{res\text{-}c}$	Exposure Frequency - Resident Child	day/yr	NA		day/yr	350	350
ET_{res}	Exposure Time	hr/day	Used to Calculate Time Fraction		hr/day	24	24
$ET_{res\text{-}a,h}$	Exposure Time - Resident Adult Hard Surface	hr/day	NA		hr/day	6	6
$ET_{res\text{-}c,h}$	Exposure Time - Resident Child Hard Surface	hr/day	NA		hr/day	6	6
$ET_{res\text{-}a,s}$	Exposure Time - Resident Adult Soft Surface	hr/day	NA		hr/day	10	10
$ET_{res\text{-}c,s}$	Exposure Time - Resident Child Soft Surface	hr/day	NA		hr/day	10	10
	Gamma Shielding Factor	unitless	No Shielding Assumed (Source Thickness = 0 cm)		unitless	Not Applied in Settled Dust Calculations	
F_i	Fraction of Time Spent in Compartment	unitless	NA		unitless	1	1
FAM	Area and Material Factor	unitless	NA		unitless	1	1
F_{in}	Fraction Time Spent Indoors	unitless	0.5	0.96	unitless	1	1
$F_{OFF\text{-}SET}$	Off-set Factor	unitless	NA		unitless	1	1
FQ_a	Frequency of Hand to Mouth - Adult	event/hr	NA		event/hr	3	1.64
FQ_c	Frequency of Hand to Mouth - Child	event/hr	NA		event/hr	17	17
$FTSS_h$	Fraction Transferred Surface to Skin - Hard Surface	unitless	NA		unitless	0.5	0.5
$FTSS_s$	Fraction Transferred Surface to Skin - Soft Surface	unitless	NA		unitless	0.1	0.1
$IFD_{res\text{-}adj}$	Age-adjusted Dust Ingestion Rate - Resident	cm^2	NA		cm^2	3,200,400	528,220
	Ingestion Rate - Adult	m^2/hr	0.0001	0.0001	NA		
	Ingestion Rate - Child	m^2/hr	0.0001	0.0002	NA		
k	Dissipation Rate Constant	yr^{-1}	NA		yr^{-1}	0	0
	Radon Release Fraction	unitless	0.1	0.4 for Rn-222 from Ra-226 decay chain	NA		
				0.02 for Rn-220 from Th-232 decay chain	NA		
	Room Area	m^2	36	9.3	10		
	Removable Fraction	unitless	0.5	0.2	unitless	Applied to EPC for	
$SA_{res\text{-}a}$	Surface Area of Fingers - Resident Adult	cm^2	NA		cm^2	49	11.5
$SA_{res\text{-}c}$	Surface Area of Fingers - Resident Child	cm^2	NA		cm^2	16	3.7
SE	Saliva Extraction Factor	unitless	NA		unitless	0.5	0.5
	Time Fraction	unitless	1	1	NA		
t_{res}	Time - Resident (for determining dissipation, k)	yr	NA		yr	26	26

Radon is evaluated in the BPRG model, but there is no entry for release fractions.

3.4.2 Dose and Risk Libraries

3.4.2.1 USEPA Calculators

Slope Factors for a given radionuclide represent the risk equivalent per unit intake (i.e., ingestion or inhalation) or external exposure of that radionuclide. In risk assessments, these SFs are used in calculations with radionuclide concentrations and exposure assumptions to estimate risk from exposure to radioactive contamination. The calculations may be rearranged to generate BPRGs for a specified level of risk. Slope Factors may be specified for specific body organs or tissues of interest or as a weighted sum of individual organ risk, termed the effective risk equivalent. These SFs may be multiplied by the total activity of each radionuclide inhaled or ingested per year, or the external exposure concentration to which a receptor may be exposed, to estimate the risk to the receptor. Slope Factors used are provided in Calculations of Slope Factors and Dose Coefficients prepared by Oak Ridge National Laboratory, Center for Radiation Protection Knowledge (ORNL/TM-2013/00).

Inhalation slope factors are tabulated separately for each of the three lung absorption types considered in the lung model currently recommended by the International Commission on Radiological Protection (ICRP) and, where appropriate, for inhalation of radionuclides in vapor or gaseous forms.

Dose Coefficient Factors for a given radionuclide represent the dose equivalent per unit intake (i.e., ingestion or inhalation) or external exposure of that radionuclide. In dose assessments, these DCFs are used in calculations with radionuclide concentrations and exposure assumptions to estimate dose from exposure to radioactive contamination. The calculations may be rearranged to generate BDCCs for a specified level of dose. DCFs may be specified for specific body organs or tissues of interest or as a weighted sum of individual organ dose, termed the effective dose equivalent. These DCFs may be multiplied by the total activity of each radionuclide inhaled or ingested per year or the external exposure concentration to which a receptor may be exposed to estimate the dose to the receptor. Dose Coefficients used are provided by the Center for Radiation Protection Knowledge.

The USEPA Calculators allow users to enter custom SFs and DCFs via the User-provided input selection. This may be an option to try to resolve SF and DCF differences between USEPA and USDON modeling efforts.

3.4.2.2 RESRADBLD

RESRAD DCF Editor, Version 2.5 (2009) is embedded as a tool in RESRADBLD. This allows for the selection of different DCFs and SFs to combine into a custom library for calculations as discussed in section 3.4.2.1. The DCF Editor has been updated periodically and accordingly so has RESRADBLD with regard to libraries. Currently RESRADBLD has the option of selecting FGR11, FGR12, FGR13 (morbidity and mortality), HEAST 2001 morbidity, ICRP 60, ICRP 72 (with 6 different ages) as well as custom editing DCFs and SFs.

Custom setting the DCFs and SFs to those used in the calculators may reduce the differences between the models.

3.4.2.1 USDON Model DCF and SF Selection

DCFs for a given radionuclide represent the dose equivalent per unit intake (i.e., ingestion or inhalation) or external exposure of that radionuclide. In dose assessments, these DCFs are used in calculations with radionuclide concentrations and exposure assumptions to estimate dose from exposure to radioactive contamination. The USDON RESRADBLD submittals to USEPA made use of two custom libraries using the RESRAD DCF Editor, Version 2.5 (2009) which is embedded as a tool in RESRADBLD. The custom library called HPNS Adult uses DCFs for external exposures from Federal Guidance Report (FGR) No. 12 (USEPA 1993), DCFs for inhalation and ingestion exposures from International Commission on Radiological Protection Publication 72 (ICRP 1995) for adults, and risk coefficients (a.k.a. SF) for total cancer morbidity from the Health Effects Assessment Summary Tables (HEAST) (USEPA 2001). The custom library called HPNS Child uses DCFs for external exposures from FGR 12 (USEPA 1993), DCFs for inhalation and ingestion exposures from ICRP 72 (ICRP 1995) for children (age 15), and risk coefficients for total cancer morbidity from HEAST (USEPA 2001).

3.4.2.4 Differences in DCF and SF between USDON RESRADBLD and EPA Calculators for External Pathway.

USACE compared RESRADBLD library DCFs to those used by the BDCC. The external dose model was chosen for comparison over the dust model for reasons discussed later in this report.

A review of Tables 3.4.3 through 3.4.5 suggest the most comparable BDCC library selection for ingestion is the ICRP 30. The ICRP 30 selection is essentially identical to the DCFs used in the RESRADBLD library with minor (<1%) differences most likely due to rounding of numbers and significant figures between the models.

As illustrated in Tables 3.4.4 and 3.4.5, the ICRP rule 107 and 60/68/72DCFs are fairly similar with the exception of Cs-137, Sr-90, and Y-90. The reasons for these differences were not apparent to USACE. The BDCC using the ICRP rule 30 selection results in identical DCFs as that used in the RESRADBLD HPNS model. As a result, if all other model assumptions and inputs were the same it would be expected that the two model's results would be similar.

The RESRADBLD user guide suggests that area sources have an assumed thickness of 0.1 cm, however discussions with Charley Yu, ANL (lead developer of RESRAD codes) and RESRADBLD outputs suggest the model sets source thickness to zero. In an email from Charley Yu to David Hays of USACE dated 28 Feb 2020, Dr. Yu referred USACE to Chapter 7 of ANL-EAD-TM-115 for discussions of area source external DCF calculations. TM-115 discusses that DCFs for area sources are calculated and set to equal FGR 12 contaminated surface DCFs when source thickness equals zero (0). USACE confirmed this by converting FGR 12 values to conventional units and comparing to the RESRADBLD DCFs.

It is unclear from the RESRAD user guide and from conversations with Dr. Yu how the RESRADBLD code calculates slope factors for area sources. Although the calculation is unclear, one assumption may be that if the HEAST 2001 library is chosen, the SF used in RESRADBLD equals that presented in FGR 13 for mortality ground plane. A comparison of these SFs is presented in Table 3.4.6.

Table 3.4.3 DCF Comparisons BDCC ICRP 30

30 DCFs Comparison External Surface or Ground Plane

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant Difference[E]
	mrem/yr per pCi/cm2		*Percent (%)[B]*	*Model[D]*	
Am-241	3.21E-02	3.21E-02	0.00	NA	No
Co-60	2.74E+00	2.74E+00	0.15	RESRADBLD	No
Cs-137	3.33E-04	3.33E-04	0.00	NA	No
Ba-137m[F]	6.84E-01	6.84E-01	0.03	RESRADBLD	No
Eu-152[F]	1.28E+00	1.28E+00	0.31	RESRADBLD	No
EU-154[F]	1.39E+00	1.39E+00	0.07	BDCC	No
H-3	0.00E+00	0.00E+00	0.00	NA	No
Pu-239[F]	4.28E-04	4.29E-04	0.23	RESRADBLD	No
Ra-226	7.52E-03	7.52E-03	0.00	NA	No
Sr-90[F]	3.31E-04	3.32E-04	0.30	RESRADBLD	No
Y-90	6.21E-03	6.21E-03	0.00	NA	No
Th-232	6.43E-04	6.43E-04	0.00	NA	No
U-235	1.73E-01	1.73E-01	0.00	NA	No
Th-231	2.16E-02	2.16E-02	0.00	NA	No
Th-232+D[A,F]	2.71E+00	2.73E+00	0.88	RESRADBLD	No
Ra-226+D[A, F]	1.96E+00	1.94E+00	0.78	BDCC	No

Notes:

[A] Calculated values (not actually presented in model output)

[B] Percent Difference equals absolute value of the difference divided by the mean.

[C] Signifcant % Difference

[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.

[E] Significance determined as greater than 30% difference.

[F] For Th-232+D calculation assumed Tl-208 = 0.3954 branch ratio.

NA = Not Applicable

Table 3.4.4 DCF Comparisons BDCC ICRP 60/68/72

ICRP DCFs Comparison External Surface or Ground Plane

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant
	mrem/yr per pCi/cm2		Percent (%)[B]	Model[D]	Difference[E]
Am-241	2.72E-02	3.21E-02	16.53	RESRADBLD	No
Co-60	2.68E+00	2.74E+00	2.36	RESRADBLD	No
Cs-137	3.49E-03	3.33E-04	165.16	BDCC	Yes
Ba-137m	6.76E-01	6.84E-01	1.21	RESRADBLD	No
Eu-152	1.26E+00	1.28E+00	1.89	RESRADBLD	No
EU-154	1.37E+00	1.39E+00	1.38	RESRADBLD	No
H-3	0.00E+00	0.00E+00	0.00	BDCC	No
Pu-239	3.31E-04	4.29E-04	25.79	RESRADBLD	No
Ra-226	7.13E-03	7.52E-03	5.32	RESRADBLD	No
Sr-90	1.91E-03	3.32E-04	140.77	BDCC	Yes
Y-90	1.28E-01	6.21E-03	181.49	BDCC	Yes
Th-232	5.31E-04	6.43E-04	19.08	RESRADBLD	No
U-235	1.63E-01	1.73E-01	5.95	RESRADBLD	No
Th-231	1.81E-02	2.16E-02	17.63	RESRADBLD	No
Th-232+D[A,F]	2.78E+00	2.73E+00	1.90	BDCC	No
Ra-226+D[A]	2.09E+00	1.94E+00	7.30	BDCC	No

Notes:
[A] Calculated values (not actually presented in model output)
[B] Percent Difference equals absolute value of the difference divided by the mean.
[C] Signifcant % Difference
[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.
[E] Significance determined as greater than 30% difference.
[F] For Th-232+D calculation assumed Tl-208 = 0.3954 branch ratio.

Table 3.4.5 DCF Comparisons BDCC ICRP rule 107

107 DCFs Comparison External Surface or Ground Plane

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant
	mrem/yr per pCi/cm2		Percent (%)[B]	Model[D]	Difference[E]
Am-241	2.55E-02	3.21E-02	22.92	RESRADBLD	No
Co-60	2.69E+00	2.74E+00	1.99	RESRADBLD	No
Cs-137	3.66E-03	3.33E-04	166.64	BDCC	Yes
Ba-137m	6.75E-01	6.84E-01	1.35	RESRADBLD	No
Eu-152	1.27E+00	1.28E+00	1.10	RESRADBLD	No
EU-154	1.37E+00	1.39E+00	1.38	RESRADBLD	No
H-3	0.00E+00	0.00E+00	0.00	NA	No
Pu-239	3.58E-04	4.29E-04	18.04	RESRADBLD	No
Ra-226	7.81E-03	7.52E-03	3.78	BDCC	No
Sr-90	1.92E-03	3.32E-04	141.03	BDCC	Yes
Y-90	1.29E-01	6.21E-03	181.63	BDCC	Yes
Th-232	5.30E-04	6.43E-04	19.27	RESRADBLD	No
U-235	1.74E-01	1.73E-01	0.58	BDCC	No
Th-231	1.78E-02	2.16E-02	19.29	RESRADBLD	No
Th-232+D[A,F]	2.56E+00	2.73E+00	6.47	RESRADBLD	No
Ra-226+D[A, G]	2.07E+00	1.94E+00	6.41	BDCC	No

Notes:
[A] Calculated values (not actually presented in model output)
[B] Percent Difference equals absolute value of the difference divided by the mean.
[C] Signifcant % Difference
[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.
[E] Significance determined as greater than 30% difference.
[F] For Th-232+D calculation assumed Tl-208 = 0.3954 branch ratio.
[G] For Ra-226 +D the BDCC includes Hg-206 and Tl-210, these were removed for this calculation.
NA = Not Applicable

Table 3.4.6 Comparison of FGR 13 and BPRG Slope Factors

SFs External surface or ground plane

	risk/yr/pCi/g	risk/yr per pCi/cm2	risk/yr per pCi/cm2	BPRG vs FGR 13
Isotpoe	RESRADBLD (heast)	FGR 13	BPRG	% Difference
Am-241	2.76E-08	1.96E-08	1.87E-08	4.92
Co-60	1.24E-05	2.19E-06	2.18E-06	0.29
Cs-137	5.32E-10	5.34E-10	5.53E-10	3.44
Ba-137m	2.69E-06	5.38E-07	5.36E-07	0.34
Eu-152	5.30E-06	1.01E-06	1.03E-06	2.06
EU-154	5.83E-06	1.09E-06	1.10E-06	0.73
H-3	0.00E+00	0.00E+00	0.00E+00	0.00
Pu-239	2.00E-10	1.91E-10	2.06E-10	7.78
Ra-226	2.29E-08	5.72E-09	6.25E-09	8.90
Sr-90	4.82E-10	3.74E-10	3.74E-10	0.04
Y-90	1.91E-08	1.67E-08	1.67E-08	0.12
Th-232	3.42E-10	3.20E-10	3.26E-10	1.74
U-235	5.18E-07	1.31E-07	1.39E-07	5.96
Th-231	2.45E-08	1.26E-08	1.24E-08	1.82
Th-232+D	5.97E-06	Not Calculated	2.00E-06	NA
Ra-226+D	8.49E-06	Not Calculated	1.52E-06	NA

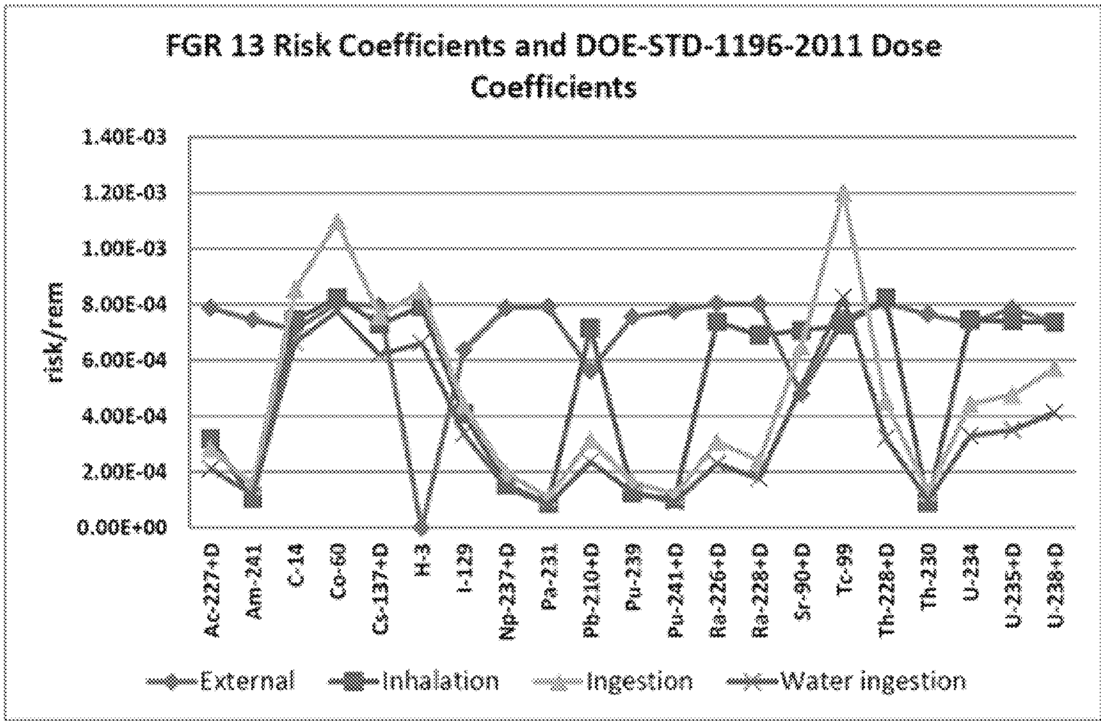
As illustrated in Table 3.4.6, the BPRG and FGR-13 SFs for HPNS radionuclides are similar (less than 10% difference). USACE also calculated SFs if the 0.01 cm thickness mentioned in the RESRADBLD user guide and a unit density of 1 g/cm3 (obtained from Dr. Yu). This calculation attempted to convert HEAST 2001 library risk/yr/pCi/g to risk/yr/pCi/cm2; however, results were 2 orders of magnitude different than FGR 13 and thus not presented or pursued further. As stated above, it is unclear to USACE how RESRADBLD performs calculations with external SFs when the HEAST 2001 library is selected.

USACE evaluations of external risk results in RESRADBLD suggest that the model calculates external risk by calculating dose and then using a conversion factor to convert dose to risk. While not discussed in the RESRADBLD user manual, the RESRAD-RECYCLE manual states; “Potential cancer risks from radiation exposure are calculated in the code by multiplying the radiation doses by latent cancer incidence risk factors. The default values for the risk factors (0.0567/Sv for workers and 0.076/Sv for the public) correspond with EPA recommendations (EPA 1991)”. USACE calculations demonstrate a consistent conversion factor of 0.076 risk per Sv (some minor variations due to rounding) appears to be used by RESRAD-BLD most radionuclide external risk calculations. There are some isotopes that this does not appear to hold true for however, thus how risk is calculated for an area source using HEAST SFs remains unclear.

It should be noted that FGR-13 changed the 0.076/Sv to 0.0846/Sv. Thus, if RESRADBLD uses the same approach as RESRAD-RECYCLE it would underestimate external risk compared to the current FGR-13 suggested conversion. Additionally, dose to risk conversion factors are isotope, pathway, and emission specific.

To illustrate that the dose to risk conversion factor is not a constant for most radionuclides, a set of 21 radionuclides was selected with various half-lives and radiation decay, including alpha-, beta-, and high energy gamma-emitters. The cancer morbidity risk coefficients published in FGR 13 (Eckerman et al. 1999) and the age- and gender-averaged effective dose coefficients published in DOE-STD-1196-2011 (DOE 2011) were used. The results are shown in Figure 1. It can be seen that the ratio for each individual pathway varies by about 1 order of magnitude, and for most radionuclides, especially for alpha-emitters, the ratio is much lower than 0.0846/Sv. It should be noted that variations occur in the external pathway risk/dose as well.

Figure 1. Isotopic Risk/Rem Per Pathway



Given the similarity in DCFs between the models, dose results between RESRADBLD and BDCC are expected to be similar when only DCFs are considered. Likewise, if FGR 13 ground plane SFs were selected as part of the HPNS custom library the risks estimated for the external pathway are expected to be similar between RESRADBLD and BPRG. Use of a constant dose to risk conversion factor is NOT recommended by USACE. It should be noted however that other differences between the models exist as discussed herein.

3.4.2.5 Differences in DCF and SF between USDON RESRADBLD and EPA Calculators for Ingestion Pathway.

USACE compared RESRADBLD library ingestion DCFs and SFs to those used by BDCC and BPRG. Significant differences were observed with DCFs and SFs depending on the ICRP rule selected in BDCC and BPRG. A review of Tables 3.4.7 through 3.4.9 suggest the most comparable BDCC library selection for ingestion is the ICRP 60/68/72. While the ICRP rule 107 - Center for Radiation Protection Knowledge selection DCFs differ by just a few percent it includes Hg-206 and Tl-210 in the Ra-226 decay chain which USACE manually set to zero for the comparison. The ICRP 60/68/72 selection is essentially identical to the DCFs used in RESRADBLD library with minor (<1%) differences most likely due to rounding of numbers and significant figures between the models.

Table 3.4.10 shows comparisons of pathway-specific cancer risks calculated based on USDON assumptions of decay using RESRAD-BUILD versus the BPRG calculator. For all pathways, the BPRG cancer risks are greater than the RESRAD-BUILD, despite the fact that the HEAST 2001 CSFs are more health-conservative than the 2014 ORNL CSFs. The biggest difference between model results appears with the ingestion pathway, possibly due to greater ingestion rate assumed for hand to mouth exposures in the BPRG Calculator. This could be due in part to the BPRG ingestion rates for the adult and child working out to being approximately 3 and 5 times, respectively, greater than the RESRAD-BUILD ingestion rates (i.e., when calculated as "apples to apples"). Please see section 3.5.2 herein for additional discussion on the ingestion pathway.

Given the similarity in DCFs between the models, dose results between RESRADBLD and BDCC are expected to be similar when only DCFs are considered. Likewise, if FGR 13 SFs were selected as part of the HPNS custom library, the risks estimated for the ingestion pathway are expected to be similar between RESRADBLD and BPRG. It should be noted however that other differences (e.g. ingestion rates) between the models exist as discussed herein.

Table 3.4.7 Ingestion DCF Comparison BDCC ICRP 30

30 DCFs Comparison Ingestion Pathway

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant
	mrem/pCi		Percent (%)[B]	Model[D]	Difference[E]
Am-241	3.64E-03	7.40E-04	132.42	BDCC	Yes
Co-60	2.69E-05	1.26E-05	72.54	BDCC	Yes
Cs-137	5.00E-05	4.81E-05	3.87	BDCC	No
Ba-137m	0.00E+00	0.00E+00	0.00	NA	No
Eu-152	6.48E-06	5.18E-06	22.30	BDCC	No
EU-154	9.55E-06	7.40E-06	25.37	BDCC	No
H-3	6.40E-08	1.55E-07	83.11	RESRADBLD	Yes
Pu-239	3.54E-03	9.25E-04	117.13	BDCC	Yes
Ra-226	1.32E-03	1.04E-03	24.11	BDCC	No
Sr-90	1.42E-04	1.04E-04	31.27	BDCC	Yes
Y-90	1.08E-05	9.99E-06	7.79	BDCC	No
Th-232	2.73E-03	8.51E-04	104.94	BDCC	Yes
U-235	2.66E-04	1.74E-04	41.87	BDCC	Yes
Th-231	1.35E-06	1.26E-06	7.06	BDCC	No
Th-232+D[A]	4.98E-03	3.94E-03	23.33	BDCC	No
Ra-226+D[A]	8.60E-03	8.03E-03	6.82	BDCC	No

Notes:

[A] Calculated values (not actually presented in model output)

[B] Percent Difference equals absolute value of the difference divided by the mean.

[C] Signifcant % Difference

[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.

[E] Significance determined as greater than 30% difference.

NA = Not Applicable

Table 3.4.8 Ingestion DCF Comparison BDCC ICRP 60/68/72

ICRP DCFs Comparison Ingestion Pathway

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant
	mrem/pCi		Percent (%)[B]	Model[D]	Difference[E]
Am-241	7.40E-04	7.40E-04	0.00	NA	No
Co-60[F]	1.26E-05	1.26E-05	0.16	BDCC	No
Cs-137	4.81E-05	4.81E-05	0.00	NA	No
Ba-137m	0.00E+00	0.00E+00	0.00	NA	No
Eu-152	5.18E-06	5.18E-06	0.00	NA	No
EU-154	7.40E-06	7.40E-06	0.00	NA	No
H-3	1.55E-07	1.55E-07	0.00	NA	No
Pu-239	9.25E-04	9.25E-04	0.00	NA	No
Ra-226[F]	1.04E-03	1.04E-03	0.39	BDCC	No
Sr-90[F]	1.04E-04	1.04E-04	0.39	BDCC	No
Y-90	9.99E-06	9.99E-06	0.00	NA	No
Th-232	8.51E-04	8.51E-04	0.00	NA	No
U-235[F]	1.74E-04	1.74E-04	0.06	BDCC	No
Th-231[F]	1.26E-06	1.26E-06	0.16	BDCC	No
Th-232+D[A,F]	3.93E-03	3.94E-03	0.18	RESRADBLD	No
Ra-226+D[A,F]	8.04E-03	8.03E-03	0.07	BDCC	No

Notes:

[A] Calculated values (not actually presented in model output)

[B] Percent Difference equals absolute value of the difference divided by the mean.

[C] Signifcant % Difference

[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.

[E] Significance determined as greater than 30% difference.

[F] Difference insignificant and likely result of rounding.

NA = Not Applicable

Table 3.4.9 Ingestion DCF Comparison BDCC ICRP Rule 107

107 DCFs Comparison Ingestion Pathway

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant
	mrem/pCi		*Percent (%)* [B]	*Model* [D]	Difference [E]
Am-241	7.55E-04	7.40E-04	2.01	BDCC	No
Co-60	1.27E-05	1.26E-05	0.95	NA	No
Cs-137	5.03E-05	4.81E-05	4.47	BDCC	No
Ba-137m	0.00E+00	0.00E+00	0.00	NA	No
Eu-152	4.96E-06	5.18E-06	4.34	RESRADBLD	No
EU-154	7.40E-06	7.40E-06	0.00	NA	No
H-3	1.55E-07	1.55E-07	0.00	NA	No
Pu-239[F]	9.29E-04	9.25E-04	0.43	BDCC	No
Ra-226[F]	1.04E-03	1.04E-03	0.39	BDCC	No
Sr-90	1.02E-04	1.04E-04	1.56	RESRADBLD	No
Y-90[F]	9.92E-06	9.99E-06	0.70	RESRADBLD	No
Th-232[F]	8.55E-04	8.51E-04	0.47	BDCC	No
U-235[F]	1.74E-04	1.74E-04	0.00	NA	No
Th-231	1.24E-06	1.26E-06	1.44	RESRADBLD	No
Th-232+D[A,F]	3.96E-03	3.94E-03	0.62	BDCC	No
Ra-226+D[A,F]	8.11E-03	8.03E-03	0.94	BDCC	No

Notes:

[A] Calculated values (not actually presented in model output)

[B] Percent Difference equals absolute value of the difference divided by the mean.

[C] Signifcant % Difference

[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.

[E] Significance determined as greater than 30% difference.

[F] Difference insignificant and likely result of rounding.

NA = Not Applicable

Table 3.4.10 Ingestion SF Comparison

RESRAD-BUILD Version 3.5 Versus Buildings Preliminary Remediation Goal Calculator

Hunters Point Naval Shipyard

HPNS ROC	RESRAD-BUILD Version 3.5 HEAST 2001 SFs [a]	RESRAD-BUILD Version 3.5 HEAST 2001 SFs (Following Unit Conversion) [a]	BPRG Calculator ORNL 2014 SFs [b]	Percent Ratio of HEAST 2001 SFs to ORNL 2014 SFs [c]	Comments
Units:	**(Risk/yr)/(pCi/g)**	**(Risk/yr)/(pCi/cm²)**	**(Risk/yr)/(pCi/cm²)**		
Am-241	2.76E-08	1.15E-06	1.87E-08	NA	HEAST 2001 external radiation infinite volume CSFs are not comparable to ORNL 2014 ground plane CSFs without a unit conversion. In the HPNS RESRAD-BUILD models, the source is defined to be an area source of thickness = 0 cm. Source concentrations are entered as dpm/m². However, the HEAST 2001 external radiation CSFs presented in the DCF HPNS-modified libraries are based on infinite volume (i.e., (Risk/yr)/(pCi/g)). If a depth or volume-based CSF is used, the source concentration should also be based on activity/mass (e.g., pCi/g or dpm/g). It is uncertain if or how the RESRAD-BUILD model bridges this discrepancy. The HPNS model outputs do not present the external radiation CSFs applied by the model. **Based on the units conversion performed assuming concrete surfaces with a contamination thickness of 0.01 cm (see footnote 'a'), All HEAST 2001 external radiation CSFs are greater than (i.e., more health protective than) the ORNL 2014 CSFs for ground plane exposures.**
Cs-137	5.32E-10	2.22E-08	5.54E-10	NA	
Co-60	1.24E-05	5.17E-04	2.18E-06	NA	
Eu-152	5.30E-06	2.21E-04	1.03E-06	NA	
Eu-154	5.83E-06	2.43E-04	1.10E-06	NA	
Pu-239	2.00E-10	8.33E-09	2.06E-10	NA	
Ra-226	2.29E-08	9.54E-07	6.25E-09	NA	
Sr-90	4.82E-10	2.01E-08	3.74E-10	NA	
Th-232	3.42E-10	1.43E-08	3.26E-10	NA	
H-3	0.00E+00	0.00E+00	0.00E+00	NA	
U-235	5.18E-07	2.16E-05	1.39E-07	NA	

Notes:

[a] HEAST 2001 CSFs presented were applied to all receptors in the RESRAD-BUILD model for the HPNS evaluations and are based on infinite soil volume. The RESRAD-BUILD model outputs provided do not present the external radiation CSFs as applied by the model. The external CSFs presented were obtained from the HPNS Adult and HPNS Child modified libraries as imported into the DCF editor program. Units conversion from (Risk/yr)/(pCi/g) to (Risk/yr)/(pCi/cm²) assumes the density of concrete (2.4 g/cm³) and a thickness of 0.01 cm.

[b] The ORNL 2014 CSFs for the external radiation pathway are based on exposures to ground plane sources.

[c] Calculation of ratios is not applicable (i.e., "NA") for this analysis because the HEAST 2001 external radiation CSFs (i.e., used in RESRAD-BUILD) are based on infinite soil volume sources and the ORNL 2014 external radiation CSFs (i.e., used in the BPRG calculations) are based on ground plane sources. In other words, the two sets of CSFs are not comparable.

3.4.2.6 Differences in DCF and SF between USDON RESRADBLD and EPA Calculators for Inhalation Pathway.

The BDCC user manual states: “The designations "F", "M", and "S" presented in the Radionuclide Table under the heading "ICRP Lung Type" refer to the lung absorption type for inhaled particulate radionuclides, expressed as fast (F), medium (M), or slow (S), as used in the current ICRP model of the respiratory tract. The inhalation slope factor value tabulated in the Radionuclide Table for each radionuclide has been selected based on the following guidelines: (1) For those elements where Table 4.1 of Federal Guidance Report No. 13 (and Table 2 of ICRP Publication 72) specifies a recommended default lung absorption type for particulates, the inhalation slope factor for that type is tabulated in the Radionuclide Table for each radioisotope of that element; (2) For those elements where no specific lung absorption type is recommended and multiple types are indicated as plausible choices, the inhalation slope factor reported in the Radionuclide Table for each radioisotope of that element is the maximum of the values for each of the plausible lung absorption types; and (3) If Federal Guidance Report No. 13 specifies risk coefficients for multiple chemical forms of certain elements (tritium, carbon, sulfur, iodine, and mercury), the inhalation slope factor value for the form estimated to pose the maximum risk is reported in the Radionuclide Table, in most cases.”

The RESRADBLD model defaults to the most conservative lung absorption type unless modified manually by the user during creation of a custom DCF library. The different methods used to select lung absorption DCFs results in significant differences in the DCFs presented between RESRADBLD and BDCC.

A review of Tables 3.4.11 through 3.4.13 suggest the most comparable BDCC library selection for inhalation is the ICRP rule 107 - Center for Radiation Protection Knowledge. This selection does have significant differences in DCFs for Eu-152, EU-154, and Th-232. It also differs from USACE calculated DCFs for Th-232+D and Ra-226+D.

Given the inhalation SFs used by USDON and the USEPA calculator defaults are the same inhalation risks are expected to be very similar between the risk models. See Table 3.4.14 and section 3.5.2.2 for additional discussions regarding the inhalation pathway.

Table 3.4.11 Inhalation DCF Comparison BDCC ICRP 30

30 DCFs Comparison Inhalation

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant Difference[E]
	mrem/pCi		*Percent (%)*[B]	*Model*[D]	
Am-241	4.44E-01	3.55E-01	22.28	BDCC	No
Co-60	3.31E-05	1.15E-04	110.60	RESRADBLD	Yes
Cs-137	3.19E-05	1.44E-04	127.46	RESRADBLD	Yes
Ba-137m	0.00E+00	0.00E+00	0.00	NA	No
Eu-152	2.21E-04	1.55E-04	35.11	BDCC	Yes
EU-154	2.86E-04	1.96E-04	37.30	BDCC	Yes
H-3	6.40E-08	9.62E-07	175.05	RESRADBLD	Yes
Pu-239	4.29E-01	4.44E-01	3.44	RESRADBLD	No
Ra-226	8.58E-03	3.52E-02	121.61	RESRADBLD	Yes
Sr-90	2.39E-04	5.92E-04	84.96	RESRADBLD	Yes
Y-90	7.88E-06	5.55E-06	34.70	BDCC	Yes
Th-232	1.64E+00	6.28E-01	89.24	BDCC	Yes
U-235	7.29E-03	3.15E-02	124.83	RESRADBLD	Yes
Th-231	8.62E-07	1.22E-06	34.39	RESRADBLD	Yes
Th-232+D[A]	1.90E+00	6.28E-01	100.56	BDCC	Yes
Ra-226+D[A]	3.10E-02	2.15E-01	149.64	RESRADBLD	Yes

Notes:

[A] Calculated values (not actually presented in model output)

[B] Percent Difference equals absolute value of the difference divided by the mean.

[C] Signifcant % Difference

[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.

[E] Significance determined as greater than 30% difference.

[F] Difference insignificant and likely result of rounding.

NA = Not Applicable

Table 3.4.12 Inhalation DCF Comparison BDCC ICRP 60/68/72

ICRP DCFs Comparison Inhalation

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant Difference[E]
	mrem/pCi		*Percent (%)*[B]	*Model*[D]	
Am-241	1.55E-01	3.55E-01	78.43	RESRADBLD	Yes
Co-60	3.70E-05	1.15E-04	102.63	RESRADBLD	Yes
Cs-137	1.70E-05	1.44E-04	157.76	RESRADBLD	Yes
Ba-137m	0.00E+00	0.00E+00	0.00	NA	No
Eu-152	1.55E-04	1.55E-04	0.00	NA	No
EU-154[F]	1.96E-04	1.96E-04	0.05	RESRADBLD	No
H-3	1.52E-07	9.62E-07	145.42	RESRADBLD	Yes
Pu-239	1.85E-01	4.44E-01	82.35	RESRADBLD	Yes
Ra-226	1.30E-02	3.52E-02	92.12	RESRADBLD	Yes
Sr-90	1.33E-04	5.92E-04	126.62	RESRADBLD	Yes
Y-90	5.18E-06	5.55E-06	6.90	RESRADBLD	No
Th-232	9.25E-02	6.28E-01	148.65	RESRADBLD	Yes
U-235	1.15E-02	3.15E-02	93.02	RESRADBLD	Yes
Th-231	1.22E-06	1.22E-06	0.00	NA	No
Th-232+D[A,F]	2.62E-01	6.28E-01	82.24	RESRADBLD	Yes
Ra-226+D[A]	2.97E-02	2.15E-01	151.43	RESRADBLD	Yes

Notes:

[A] Calculated values (not actually presented in model output)

[B] Percent Difference equals absolute value of the difference divided by the mean.

[C] Signifcant % Difference

[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.

[E] Significance determined as greater than 30% difference.

[F] Difference insignificant and likely result of rounding.

NA = Not Applicable

Table 3.4.13 Inhalation DCF Comparison BDCC ICRP rule 107

107 DCFs Comparison Inhalation

Isotpoe	BDCC	RESRADBLD	Difference	Conservative	Significant
	mrem/pCi		Percent (%)[B]	Model[D]	Difference[E]
Am-241	3.63E-01	3.55E-01	2.23	BDCC	No
Co-60	1.22E-04	1.15E-04	5.91	BDCC	No
Cs-137	1.54E-04	1.44E-04	6.71	BDCC	No
Ba-137m	0.00E+00	0.00E+00	0.00	NA	No
Eu-152	3.67E-04	1.55E-04	81.23	BDCC	Yes
EU-154	4.26E-04	1.96E-04	73.91	BDCC	Yes
H-3	1.07E-06	9.62E-07	10.63	BDCC	No
Pu-239[F]	4.48E-01	4.44E-01	0.90	BDCC	No
Ra-226	3.81E-02	3.52E-02	7.91	BDCC	No
Sr-90	6.07E-04	5.92E-04	2.50	BDCC	No
Y-90	6.55E-06	5.55E-06	16.53	BDCC	No
Th-232	9.47E-02	6.28E-01	147.59	RESRADBLD	Yes
U-235	3.38E-02	3.15E-02	7.04	BDCC	No
Th-231	1.40E-06	1.22E-06	13.74	BDCC	No
Th-232+D[A]	3.33E-01	6.28E-01	61.39	RESRADBLD	Yes
Ra-226+D[A]	7.83E-02	2.15E-01	93.18	RESRADBLD	Yes

Notes:

[A] Calculated values (not actually presented in model output)

[B] Percent Difference equals absolute value of the difference divided by the mean.

[C] Signifcant % Difference

[D] Conservative Model would result in higher dose if all other things (includeing model assumptions) equal.

[E] Significance determined as greater than 30% difference.

[F] Difference insignificant and likely result of rounding.

NA = Not Applicable

Table 3.4.14 Inhalation SF Comparison BPRG

Isotope	RESRADBLD USDON HPNS test case, from output report	FGR 13 from RESRADBLD Library	Heast from RESRADBLD library	ICRP 72 from RESRADBLD library	Convert dpm to pCi	BPRG Calculator
	risk per dpm	risk per pCi	risk per pCi	risk per pCi	dpm*2.22	risk per pCi
Am-241	1.70E-08	3.34E-08	2.81E-08	3.77E-08	3.77E-08	3.77E-08
Co-60	4.55E-11	8.18E-11	3.58E-11	1.01E-11	1.01E-10	1.01E-10
Cs-137	5.10E-11	1.22E-10	1.19E-11	1.12E-10	1.13E-10	1.12E-10
Eu-152	8.56E-11	1.52E-10	9.10E-11	1.90E-10	1.90E-10	1.91E-10
Eu-154	9.51E-11	1.74E-10	1.15E-10	2.11E-10	2.11E-10	2.06E-10
H-3	3.84E-13	7.84E-13	1.99E-13	8.51E-13	8.52E-13	8.47E-13
Pu-239	2.48E-08	4.66E-08	3.33E-08	5.51E-08	5.51E-08	5.55E-08
Ra-226	1.27E-08	2.68E-08	1.15E-08	2.82E-08	2.83E-08	2.82E-08
Sr-90	1.95E-10	4.00E-10	1.05E-10	4.25E-10	4.33E-10	4.25E-10
Th-232	1.95E-08	4.07E-08	4.33E-08	4.33E-08	4.33E-08	4.33E-08

Note that USDON RESRADBLD output report SF when coverted to pCi matches ICRP 72 and BPRG SFs.

3.4.3 Conceptual Model Differences

3.4.3.1 The USDON modeled RESRADBLD room and source consists of the floors only (1 plane). RESRADBLD is extremely flexible with regard to the number and location of sources. The BDCC and BPRG calculators' room and source is fixed as floors, walls, and ceiling (6 planes). Figures 2 and 3 illustrate this fundamental difference. Note that although shown as smaller circles the source in each model represents the entire plane (floor, wall, ceiling) surface.

3.4.3.2 Table 3.4.15 presents the differences between the 1 and 6 source site conceptual models.

Figure 2. USDON Modeled Sources

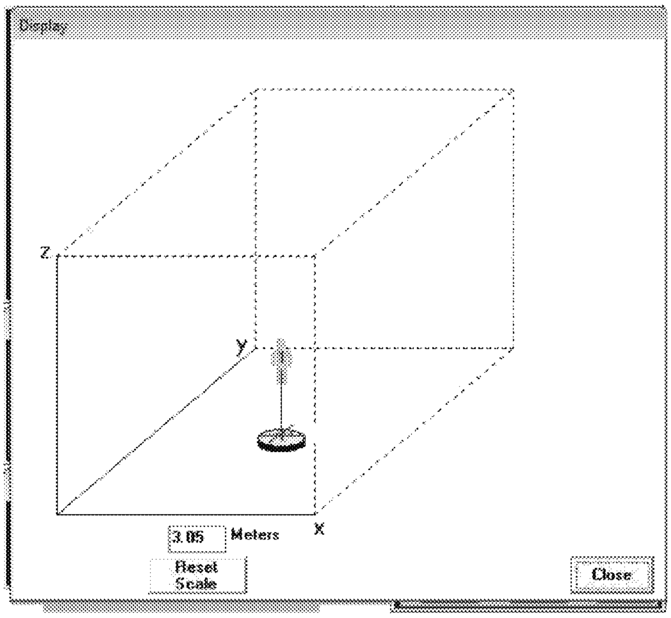
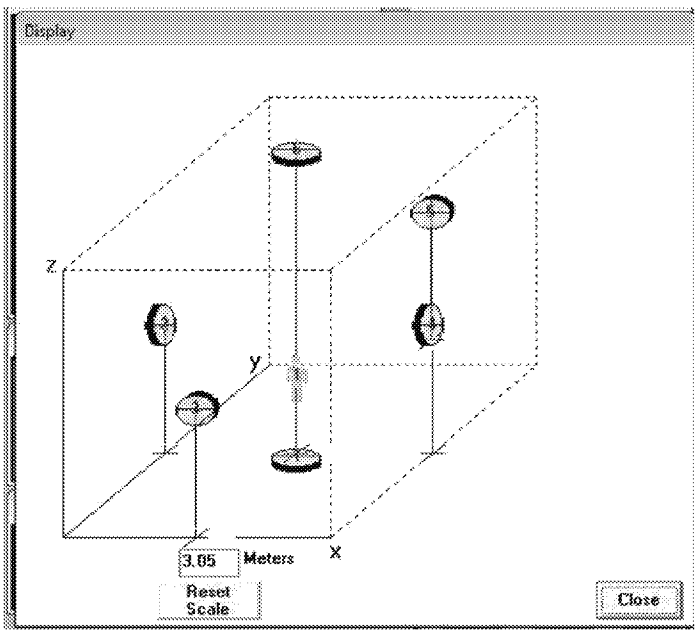
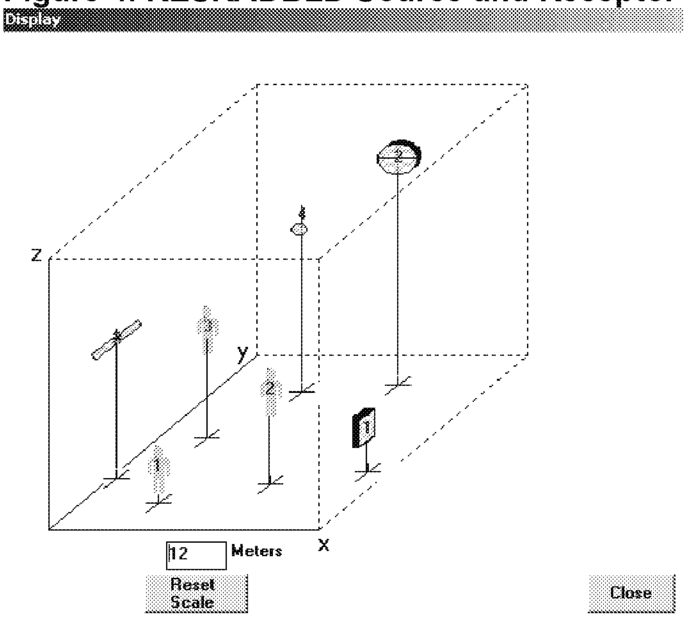


Figure 3. BDCC and BPRG Modeled Sources



3.4.3.3 RESRADBLD has significant flexibility for source numbers, types (line, point, volume, area), source locations, and receptor locations as illustrated in Figure 4. The BDCC and BPRG calculators do not have the flexibility for users to change source numbers, types, or locations. Source types are accounted for in the calculators as a part of the model and media selection as in FGR 13 (ground plane, and various source depths). The calculators do have options of receptor locations as well (center, center of wall, average, and corner). Accordingly, modifying the RESRADBLD sources to match the USEPA Calculator fixed sources and modifying the USEPA calculator receptor location to match that used by USDON would facilitate model comparisons.

Figure 4. RESRADBLD Source and Receptor Flexibility



3.4.3.4 Source Discussions

RESRADBLD allows several details of sources to be considered. The user manual states: "The RESRAD-BUILD code can compute the attenuation due to a shielding material between each source-receptor combination when calculating the external dose. The user can select the shielding material from eight material types and input the thickness and density of the shielding material. The user may also define the source as a point, line, area, or volume source. Volume sources can be composed of up to five layers of different materials, with each layer being homogeneous and isotropic."

The calculator source types are selected by contaminated media (3-D external, air, and dust) to be considered. Shielding is not assumed in the calculators.

3.4.3.5 Source Removal Discussions

Conceptual model differences also include source removal factors such as the following:

- Radioactive decay
- Cleaning (vacuuming, dusting, etc.)
- Removable fraction (degradation)
- Air fraction and air exchanges

RESRADBLD and the calculators account for radioactive decay. RESRADBLD calculates decay and daughter concentrations along with the dose and risk of each over time. As initial isotopic sources are depleted by decay their modeled results decline. Daughter modeled results may increase accordingly.

The calculators offer three input options to users to account for decay which include:

- Assumes secular equilibrium throughout chain (no decay)
- Does not assume secular equilibrium, provide results for progeny throughout chain
- Does not assume secular equilibrium, provides results for selected isotopes only

The calculators provide a point in time output with regard to decay options. Currently the initial source is not removed with decay, thus the calculator results are conservative.

The calculators account for source removal from routine cleaning such as dusting and vacuuming. Once a portion of a source is removed it is no longer considered in the dose and risk calculations. This source removal is different than that modeled in RESRADBLD.

RESRADBLD accounts for source removal by a removable fraction (RF) input. The removable fraction is defined in the user manual as ".... the fraction of a point, line, or area source that can be removed. The balance of the source is assumed to remain fixed." This differs from the calculator cleaning removal as the removable fraction is essentially a degradation or erosion of the source. This eroded portion of the source is then available for exposure to receptors via the ingestion and inhalation pathways. The external dose and risk are reduced as the source is removed. A source activity mass balance is maintained in the RESRADBLD model accounting for all exposure pathways.

3.4.3.6 USDON RF Discussion

The USDON assumed a RF of 20% as a conservative value. Based on historical data, this is likely overconservative and a source of differing results between the different modeling approaches.

There appears to be some confusion between agencies as to the differences between source removal as part of cleaning and as part of removable fraction as tyhey relate to modeling conditions at HPNS. The reason for the confusion depends on what model is being referred to. As discussed above, the two removal mechanisms are in fact different and handled differently between the modeling. Either model approach can be changed to account for each source removal mechanism; however, larger differences between the models exist as discussed herein and due to those, an apples to apples comparison based on source removal is not practical.

As an example, the calculators' dust model could be ran just using the source activity representative of a 20% removable fraction and that dose or risk added to the external results; however, the number of source planes as discussed in paragraph 3.4.3.1 makes this difficult at best and impractical from a mass balance and cleaning or air dispersion perspective. Alternatively, the RESRADBLD removable fraction cannot be set to match the cleaning removable fraction as the removable fraction mass balance results in dose and risks via other pathways. One compromise to best evaluate models may be to just use the external dose and risks input parameters and/or models.

The USACE has calculated residential risks and doses using the RESRADBLD based on RF = 0.01 and 0.2 as presented below (assuming wall and floor contamination and 11 ROCs modeled as 11 individual sources, per the USDON method). However, instead of adult exposure beginning at year 6 (i.e., per the USDON calculations), the adult exposure begins at year 7. Based on the calculations, the change in RF has a much greater impact on dose than on risk.

Table 3.4.3.15 Potential Impact of RF to RESRADBLD Output

Removable Fraction	Risk	Dose (mrem/yr)
0.01	3.98E-04	20.6
0.2	4.03E-04	32.8
Delta (% Increase)	1.3%	59%

Please see section 3.5.2 for additional discussions on evaluating dose and risk related to the RF.

3.4.3.7 Model Discussions

The calculators allow for three different media to be selected (3D external; air; and dust). The 3D model only accounts for external exposure. The air model accounts for inhalation and external submersion exposure. The dust model accounts for ingestion and external exposures. Because dust can be removed through cleaning the model appropriately accounts for ingestion and external exposures.

All three media models can be ran at the same time and can result in combined output results as well as the individual contributions from isotopes and pathways in report tables. The potential overlapping of 3D and dust media external exposure should be considered. EPA's BPRG Dust Deposition Calculator Exposure occurs via two exposure routes: external exposure (ground plane assumed for HPNS) and ingestion. Incidental ingestion of dust occurs when hands contact dust-laden surfaces and then contact the mouth. Variation is allowed for contact with hard and soft surfaces, as the transfer to skin varies on surface type. External exposures in the BPRG settled dust model do not include resuspension or the air submersion pathway.

The RESRADBLD model combines all pathways and media into output results as well as presents the individual contributions from isotopes and pathways in report tables.

Conceptual differences are highlighted in the residential exposure factors used in both models. Examples of differences noted include inhalation exposure factors that are applied in the RESRAD-BUILD model that are not used in the BPRG Dust Deposition Calculator. In the BPRG Calculator, skin surface areas are assumed for the fingers that contribute to the calculations of ingestion risks, via hand to mouth exposure, which are not used in the RESRAD-BUILD calculations of ingestion risks.

3.4.3.8 Other Observations

The USDON report and modeling makes what appear to be very conservative assumptions such as all isotopes are combined into sources as if all are actually together. The HPNS data suggests that contamination between buildings is comprised of different isotopes depending on the operations in that building. This combining of all sources appears convenient for modeling but unnecessarily complicates the evaluation of protectiveness and evaluation between models. As an example, the combination of isotopes could be determined to exceed the CERCLA acceptable risk range, but that combination of isotopes may not actually exist. The actual isotope combinations for a specific building may result in no unacceptable risk.

As discussed, the USDON RESRADBLD modeled source is the floor. However, the HPNS Area G workplan discusses MARSSIM Class one surveys of walls. A MARSSIM Class one area, by definition, has the potential to exceed the cleanup levels. As such it would seem reasonable to add the walls to the RESRADBLD model. Additionally, the entire surfaces of floors and walls are not likely to be uniformly contaminated post remediation however this is a conservative assumption.

The calculator 3D external and dust calculator media selection models differ in external dose and risk equations in that the 3D model includes an area factor to account for the source size versus an infinite plane source while the dust external pathway model does not. Accordingly, external results differ between the models although all other inputs and assumptions are the same.

The media specific focus of the BPRG is driven by its development as a PRG calculator and to remain consistent with the USEPA chemical PRG calculator. Likewise, the BDCC appears to have been developed with the intent for consistency between it and the BPRG calculator. Conservative aspects of PRG development such as use of the 90th percentile exposure values, etc. result in conservative risk assessment results as well. While conservative, the approach is consistent with USEPA risk assessment process and PRG development for chemicals (most notably from dust data as a result of the World Trade Center public safety investigations).

3.5. Consistent Conceptual Site Model and Modeling Approach Discussions

Because the modeling approaches differ a consistent and realistic Conceptual Site Model (CSM) should be agreed upon by both USDON and USEPA. Realistic pathways, exposure scenarios, and activities should be agreed upon before modeling is completed and compared. Actual number of isotopes potentially in a building, presence of dusts, renovation worker or residential receptors, etc. are some of the items that should be agreed to. Some specific model aspects related to the CSM are discussed below.

3.5.1 Number of Sources

USACE modeled six sources in RESRADBLD (as assumed in the calculators' site conceptual model) for the indoor worker scenario. The ICRP 30 DCFs were selected for the BDCC. Table 3.5.1 presents the results of that effort. Differences between modeled results are still significant, however, with a couple exceptions the differences may be due to the half life of the contaminant being shorter than the exposure period (25 years). Since RESRADBLD decays the source but the calculators do not as a default calculation, RESRADBLD results are typically lower than the calculators. Notable exceptions are Th-232+D and Pu-239. It should be noted that the calculators can account for decay in decay chains by the user picking the site-specific, then user provided options, then change progeny half-lives to match the parent.

Table 3.5.1 Six Sources Modeled Adult Worker External Exposure

Parent ROC	Contributing Progeny	Input Concentration (dpm/m^2)	Input Conversions		Adult Worker				Differences		Potential Explanation
			pCi/m2	pCi/cm2	RESRAD BLD Risk	RESRAD BLD Dose mrem	BPRG 3D Risk	BDCC Dose mrem	% Difference Dose	% Difference Risk	Hallife much longer than Exposure period?
^{241}Am		10,000	4504.5	0.45045	3.62E-08	5.74E-02	4.04E-08	7.10E-02	21.2	11.0	Yes
^{60}Co		500,000	225225	22.5225	3.68E-05	4.81E+01	1.08E-04	4.65E+02	162.5	98.3	No, much shorter
^{137}Cs	^{137m}Ba	500,000	225225	22.5225	2.22E-05	2.91E+01	4.34E-05	5.53E+01	62.1	64.6	No, roughly equal
^{152}Eu		500,000	225225	22.5225	3.33E-05	4.41E+01	2.56E-04	3.20E+02	151.6	154.0	No, much shorter
^{154}Eu		500,000	225225	22.5225	2.80E-05	3.69E+01	2.17E-04	2.75E+02	152.7	154.3	No, shorter
^{3}H		500,000	225225	22.5225	NA	NA	NA	NA	NA	NA	No
^{239}Pu	^{235m}U	10,000	4504.5	0.45045	6.34E-07	8.74E-01	1.40E-06	1.20E-04	199.9	75.3	Yes
^{226}Ra	^{222}Rn+D	10,000	4504.5	0.45045	3.50E-06	2.82E+00	3.57E-06	4.58E+00	47.6	2.0	Yes
	^{210}Pb+D	10,000	4504.5	0.45045							
	^{210}Po+D	10,000	4504.5	0.45045							
^{90}Sr	^{90}Y	100,000	45045	4.505	4.77E-08	5.99E-02	4.09E-11	1.52E-05	199.9	199.7	No, roughly equal
^{232}Th		3,650	1644	0.164	1.27E-05	5.75E+00	3.97E-06	3.63E+00	45.2	104.7	Yes
	^{228}Ra+D	3,650	1644	0.164							
	^{228}Th+D	3,650	1644	0.164							
^{235}U	^{231}Th	48,800	21982	2.198	3.09E-06	4.26E+00	6.83E-06	2.26E+00	61.3	75.4	Yes

Assumptions:

RESRAD BLD	BPRG/DCC
entire floor, 4 walls and ceiling are sources	3D model (entire floor, entire walls, and ceiling are sources)
no removable/no dusts	no removable/no dusts
no ingestion or inhalation pathways	no ingestion or inhalation pathways
time zero is max dose	BDCC = mrem/yr thus X 25 for 25 years exposure
receptor center of concrete room	receptor center of concrete room
	BDCC ICRP rule 30

3.5.2 Other Pathway Considerations

3.5.2.1 Ingestion

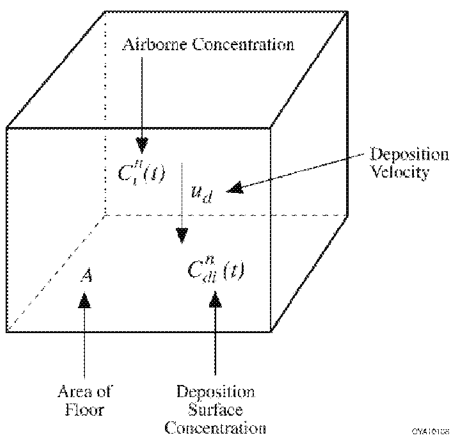
USEPA and USDON have each looked at the different ways of modeling ingestion. Focus has primarily been on the ingestion rates based on finger surface areas and frequency of hand to mouth. The pathway comparisons for the different models should also be considered. Two (2) considerations are the direct ingestion and indirect ingestion pathways in RESRADBLD.

The USEPA models do not distinguish between direct ingestion (injection of the source) and indirect ingestion (ingestion of dust generated from erosion of the source). This is because of the starting point of the USEPA ingestion models is with dust concentration. The USEPA model does not erode a source into air and dust fractions. To date the model comparisons have been compared by the RF (20% of criteria) equal to the dust concentration. This simply is not the case and not how RESRADBLD models the ingestion dose or risk.

Direct ingestion is set to zero, but indirect ingestion does occur in the current USDON model. RESRADBLD modeled concentration for indirect ingestion is a complicated set of equations that reduce the activity for ingestion significantly. Since the detailed output report from RESRADBLD does not state the resulting dust concentrations it can be difficult to determine the equivalent concentration to input into the USEPA models for comparison.

As an example: RESRADSBLD determines the indirect ingestion activity by multiplying the RF by the air fraction (0.1 in the USDON model). This reduction should be applied to the USEPA input dust activity at a minimum. The dust activity is reduced further by the air exchange rate (0.45 in the USDON model) and movement of air into other model compartments (rooms). Without accounting for air exchange or movement a simplistic model of the dust generation and ultimate concentration is presented in Figure 4. The calculated airborne concentration is presented in the RESRADBLD detailed report, however, it is modified by air exchanges and resuspension. These inputs could be set to zero to better match the USEPA model or the USEPA concentration input could be adjusted accordingly. The USACE evaluated the impact of setting air exchange and resuspension to zero and as expected, dose and risk increased significantly in the RESRADBLD output.

Figure 4. Simplistic Dust Concentration Model



Direct ingestion may also be considered to better compare the different models. Assuming 20% of release criteria activity is directly ingested would make the USDON and USEPA models more comparable with regard to ingestion.

As an example, USACE modified the RESRADBLD source inputs for air fraction and direct ingestion. Mass balance must be maintained thus any removable fraction of the source that is directly ingested cannot be available for indirect ingestion or inhalation.

To determine the magnitude of use of direct ingestion a direct ingestion value representing the fraction of the hourly ingestion of 100% of the removable fraction over the source lifetime was utilized. This was calculated as removable fraction (0.2) divided by the USDON source lifetime in hours (9490 days * 24 hours/day = 227,760 hrs) and equaled 8.78E-7/hr. Exposure duration was set at 365 days. All other USDON model inputs (e.g. receptor and room inputs) were unchanged. As shown in Table 3.5.2 this increased the dose and risk by approximately a factor of seven (7). While this example does not account for all the differences between the USDON and USEPA models it does demonstrate that use of direct ingestion brings the various model results closer together.

TABLE 3.5.2.1 Ingestion Pathway Scenario Comparison RESRADBLD

Source	Isotope	Default case (indirect ingestion) mrem	Direct ingestion case mrem	Direct case/Default Mrem	Default case (indirect ingestion) risk	direct ingestion case risk	direct case/default Risk
1	Am-241 (+D)	3.51E-02	2.21E-01	6.30E+00	1.29E-09	8.12E-09	6.29E+00
2	Co-60	9.96E-03	7.65E-02	7.68E+00	8.26E-09	6.34E-08	7.68E+00
3	Cs-137	2.30E-02	1.50E-01	6.52E+00	1.72E-08	1.12E-07	6.51E+00
4	GD-152/Eu-152	2.91E-03	1.90E-02	6.53E+00	3.77E-09	2.57E-08	6.82E+00
5	Eu-154	3.92E-03	2.78E-02	7.09E+00	6.12E-09	4.35E-08	7.11E+00
6	H-3	2.75E-05	1.89E-04	6.87E+00	6.19E-11	4.26E-10	6.88E+00
7	Pu-239 (+D)	3.43E-02	2.15E-01	6.27E+00	1.69E-09	1.05E-08	6.21E+00
8	Ra-226 (+D)	6.42E-02	4.59E-01	7.15E+00	1.84E-08	1.67E-07	9.08E+00
9	Sr-90	1.40E-02	9.16E-02	6.54E+00	8.76E-09	5.71E-08	6.52E+00
10	Th-232 (+D)	1.56E-02	1.10E-01	7.05E+00	5.57E-09	4.39E-08	7.88E+00
			Average Ratio	**6.80E+00**		Average Ratio	**7.10E+00**

All source inputs the same (as modeled by USDON) except for the below:
Default: Indirect Ingestion Source input: 0.0 Direct, 0.1 Air Fraction, 0.2 Removable Fraction.
Default: Assumes removable becomes dust, modified by air exchanges and resuspension, and is ingested. Some dose and risk from inhalation and submersion as well.
Direct Ingestion Source input: 8.78E-7 Direct, 0.0 air fraction, 0.2 Removable Fraction.
Direct ingestion assumes removable fraction is ingested directly over the USDON stated source lifetime.
Note that input values must maintain mass balance, e.g. if all removable is ingested then none can be inhaled, etc.

3.5.2.2 Inhalation

The USEPA calculators have a separate model for dose and risk from contaminated Air. Inhalation is a pathway considered in RSRADBLD from the erosion of the source. As discussed in section 3.5.2.1 a mass balance between air and dust on surfaces must be maintained. The RESRADBLD detailed output report presents the calculated air concentration modeled. For model comparison USACE took this concentration from the model discussed in section 3.5.2.1 and entered it into the BPRG calculator Air model. Results are presented in table 3.5.2.2.

Table 3.5.2.2 demonstrates that differences in Air pathway dose and risk calculations between models are relatively minor. Although a key aspect in terms of CSM (include or not include inhalation) reasons for the differences in Air/inhalation pathway results were not evaluated further in this evaluation.

TABLE 3.5.2.2 Comparison of Air/Inhalation Pathway Results

Source	Isotope	RESRADBLD mrem	BDCC mrem	RESRADBLD Risk	BDCC Risk	mrem percent difference	Risk percent difference
1	Am-241	8.93E-01	6.45E-01	7.58E-08	7.90E-08	32	4
2	Co-60	1.70E-02	8.36E-03	7.86E-09	8.70E-09	68	10
3	Cs-137	3.07E-03	1.31E-02	1.08E-08	1.14E-08	124	5
4	Eu-152	2.00E-02	2.93E-02	1.72E-08	1.84E-08	38	7
5	Eu-154	2.46E-02	4.38E-02	1.81E-08	2.60E-08	56	36
6	H-3	8.63E-06	8.51E-05	1.15E-10	8.16E-11	163	34
7	Pu-239	8.66E-01	7.99E-01	1.11E-07	1.17E-07	8	5
8	Ra-226+D	4.61E-02	6.80E-02	9.18E-08	2.82E-07	38	102
9	Sr-90	2.51E-02	1.05E-02	8.31E-09	8.76E-09	82	5
10	Th-232+D	1.37E+00	2.17E-01	1.25E-07	2.09E-07	145	50
	Rn-220+D	2.87E-02	5.37E-02	2.35E-08	9.03E-08	61	117
	Rn-222+D	1.82E-01	3.96E-01	2.18E-07	2.23E-07	74	2

All source inputs the same (as modeled by USDON) except for 1 year exposure time.

3.5.2.3 Submersion

Dose and risks from the submersion and radon pathways were not evaluated.

4.0 Summary

Significant differences exist between the model conceptual approaches used by the USDON and USEPA. Differences between the models vary with regard to conservativeness with the USDON RESRADBLD being more conservative in some aspects and the USEPA calculators more conservative in others.

Discussions in Section 3 suggest that common ground between the two models may not be possible without significant modifications to assumptions and inputs or post output processing of data. That being stated, the two modeling approaches can be made more comparable with a realistic and consistently applied conceptual site model and perhaps so within some agreed to model uncertainty.

5.0 Conclusions

Conclusions are captured in the answers to evaluation questions 1 and 2 below.

1. Why do results differ between RESRADBLD and both the BDCC and BPRG calculators?

Significant differences exist between the RESRADBLD and USEPA calculators. These include: DCF and SF selection; conceptual exposure model differences such as six (6) sources versus one (1); ingestion and transfer factors; and, source removal mechanisms such as air exchanges, cleaning, and radioactive decay.

2. What can be done to reduce the differences between model results?

The USACE approach demonstrates that there are several things that can be done to reduce the differences between the models.

a. Establishing a consistent source and receptor conceptual site model to be utilized by both the Calculators and RESRADBLD. As an example, adding the walls and use of direct ingestion factors to the RESRADBLD HPNS model and use the center receptor location in the USEPA calculators.
b. Using the SF and DCF editors to set these factors equal in each model.
c. Set common media/pathway of concern (Air, Dust, 3D external).
d. Use post output processing of results to modify results (e.g. determine and subtract the exposure from the ceiling source in the Calculators).
e. Multiple runs of the Calculators to account for radioactive decay could be done or use output option two (2) site specific user provided and change progeny half-lives to match parent as well as performing a sensitivity analysis in RESRADBLD for parameters that cannot be changed.

6.0 Recommendations

Recommendations are captured in the answers to evaluation questions 3 and 4 below.

3. What should USEPA consider in determining the protectiveness of the HPNS criteria?

Consistent and realistic Conceptual Site Model. In addition to the model differences and varying input parameters discussed herein USEPA should consider the expected dust levels at HPNS post remediation. Survey data has historically indicated that there is little to no residual activity that is removable. Therefore, it is unlikely that significant contaminated dusts will remain and as such use of the air and dust calculator models may be overly conservative.

Model uncertainty should be considered. As approximations, all models have an associated uncertainty which should be considered. Using the probabilistic report of RESRADBLD or uncertainty analysis may demonstrate a range of results or an uncertainty that provides justification given the calculator results. Additionally, it should be noted that FGR-13 discusses significant uncertainty in slope factors for key HPNS isotopes of concern such as Ra-226. As such, significant uncertainty exists in risk outputs and this uncertainty should be considered when comparing differences in risk models.

Consider use of RESRADBLD given its flexibility. Alternatively, A risk assessment could be performed on the USDON proposed RGs without using RESRADBLD or BPRG (e.g. hand calculations, MCNP, GoldSim, RAGS, etc.).

4. What recommendations, if any, could be provided by USEPA to USDON regarding modeling at HPNS?

Consistent and realistic Conceptual Site Model. Recommend that the USDON provide modeling better correlated to the conditions found at HPNS and consider using specific DCFs and SFs agreed to by both USDON and USEPA.

a. The removable fraction (RF) of 0.2 seems high. Based on reported wipe sample data it is recommended that a RF of zero or 0.01 may be more appropriate.
b. Account for direct ingestion in the RESRADBLD model.
c. Expected contamination (isotopes and mixtures) in Buildings should be realistically grouped and model runs conducted per group.
d. Contamination of the four walls of a room, rather than just floor contamination, be modeled in the RESRADBLD model. Source area should be considered as well as it is unlikely that entire floors and walls will be contaminated uniformly.

7.0 References

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